Tunnel of Terror: "The Big Dig" Ceiling Tile Collapse

Leadership ViTS Meeting
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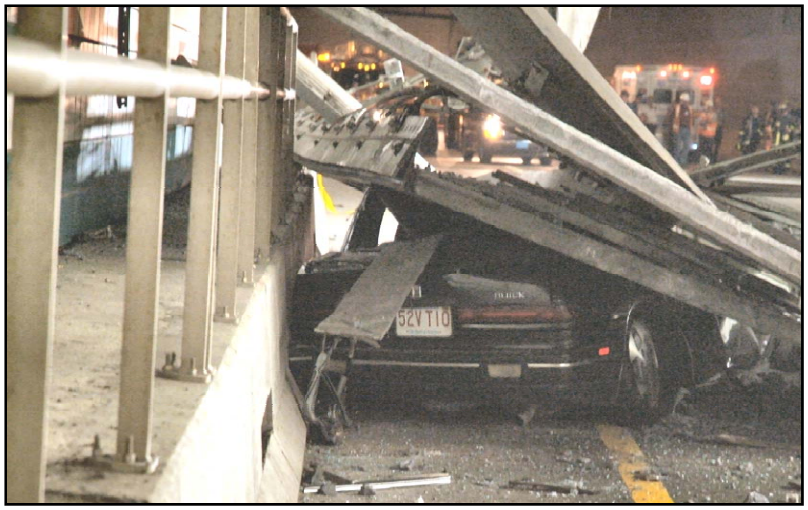
The Ceiling Collapse

- In 1999, the suspension of concrete panels from the ceiling of tunnels running beneath the city of Boston, MA, completed the most expensive roadway project in U.S. history (est. $15 billion).

- The Big Dig project, as this project for the I-90 connecter tunnel had become known, had finished over budget and behind schedule.

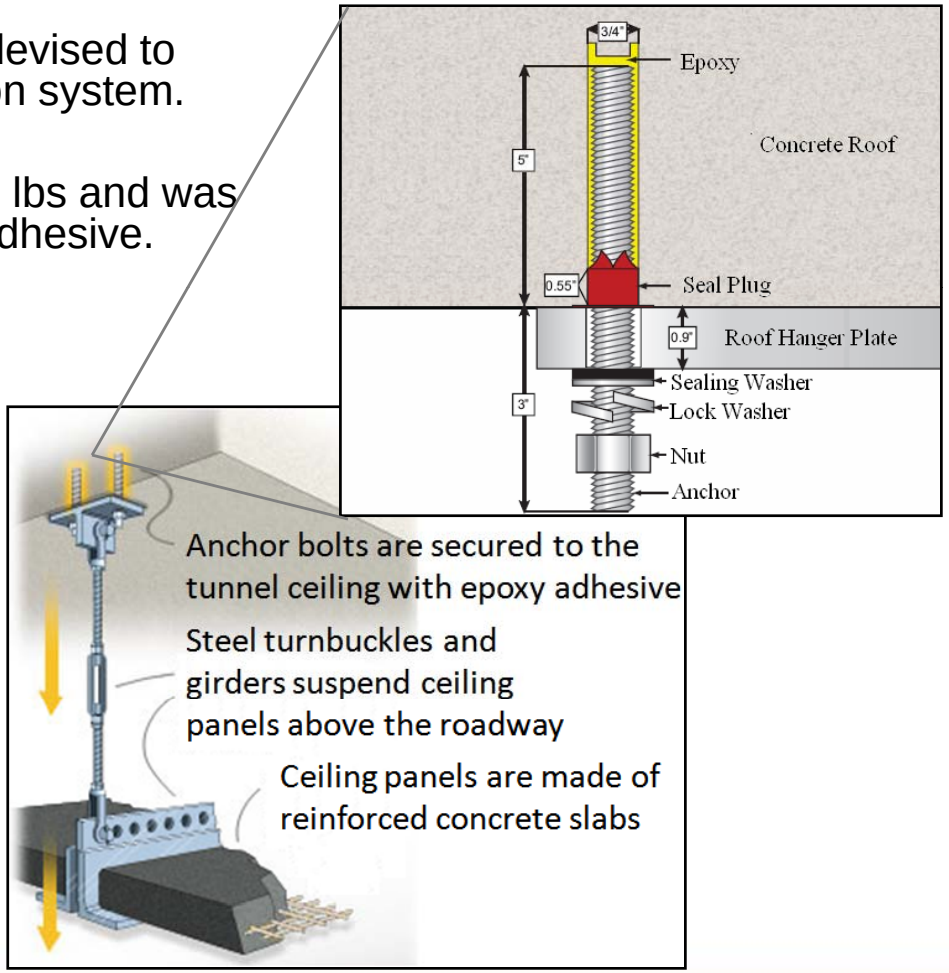


- At approximately 11 p.m. on July 10, 2006, four concrete panels detached from the ceiling of the tunnel and fell onto traffic below.

- At least 3 concrete panels with a combined mass of 24,000 lbs crushed a passing car, killing the passenger and injuring the driver.

Critical Choice of Materials

- The suspended concrete panel design was devised to assist airflow as part of the tunnel's ventilation system.
- Each panel weighed between 5,000 to 6,000 lbs and was secured to the ceiling with bolts and epoxy adhesive.
- A "Fast Set" epoxy formulation manufactured by Power Fasteners Incorporated was used instead of the "Standard" epoxy formulation utilized in most tunnel ceiling applications.
- The "Fast Set" epoxy was more susceptible to creep and not suitable for the application. The installation team claimed to be unaware of the different properties between the two epoxies.
- The anchor bolts ultimately pulled out due to epoxy creep. Post failure inspections discovered that a significant number of anchor bolts were similarly affected.



Proximate Cause

- The epoxy adhesive securing the anchor bolts underwent creep deformation and fracture, allowing the 5,000 – 6,000 lb concrete panels to pull free from the ceiling.

Root Cause/Underlying Issues

- Design flaws and ineffective communication of hazards.
  - Project engineers were cited to have expressed concerns that the heavy concrete panels were inherently hazardous.
  - No documentation was provided by the supplier to clearly distinguish between the different epoxy formulations.
  - Neither the contractors nor design consultant questioned which type of epoxy was used.
- Independent verification was bypassed, and no subsequent inspections were performed.
  - The Massachusetts Highway Department chief engineer abrogated his independent role and allowed the MTA to certify safety on his behalf.
  - After the initial installation tests in 1999, no inspection or testing occurred over the next 7 years.
- Reduced margins on critical components increased the susceptibility to creep.
  - Under cost and schedule pressure, the number of anchor bolts was cut by 40%.
  - The lack of side supports for the ceiling panels resulted in a single point failure mode.
- Management ignored advice to conduct annual inspections of bolted ceiling systems.
  - The NTSB cited the MTA for failing to inspect the ceiling despite known failures of similar systems and warnings from other MTA tunnel operators.

NASA Applicability

- It is important not to allow cost and schedule pressures to overrule warnings of off-nominal behavior. "Listen to the hardware."
- Reducing margins and factors of safety without warrant increases susceptibility to failure. Inherently hazardous designs should be thoroughly analyzed in the context of a worst case scenario.
- Components used in critical applications must be well understood. Engineers and project team members must have a deep understanding of all materials used as well as their key failure modes.
- Independent reviews and assurance should not be compromised in their depth of penetration, rigor, or frequency. Regular inspection and testing are critical components for proper maintenance.

Post accident, thousands of anchor bolts were declared unreliable. A second mechanical expansion anchor bolt was ordered to be added to each suspect bolt, which cost $54 million in the first year.

To date, litigation settlements have totaled over $400 million.